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SUMMARY REPORT:

CHARACTERIZATION OF PARTICULATE FOUND IN APARTMENTS AFTER DESTRUCTION OF THE WORLD TRADE CENTER

Requested by:

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TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

FIGURES

TABLES

TABLES

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1.0 INTRODUCTION

Immediately following the destruction at the World Trade Center on 11 September 2001, the EPA and OSHA began to monitor the air and soil around the World Trade Center site (Ground Zero) to determine the presence of asbestos, lead, polychlorinated biphenyls (PCBs), polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and volatile organic compounds.

A lack of information about the environmental safety of their homes soon became of great concern to the 50,000 residents of lower Manhattan surrounding Ground Zero. Residents who were allowed to remain in their homes did not know if they were at risk from contamination in their homes, and residents who had been told to stay out of their homes did not know when it would be safe to return. Schools and businesses shared similar concerns.

A "Ground Zero" Elected Officials Task Force was formed to respond to the concerns of the residents. On 15 September 2001, the Task Force requested that an independent environmental assessment of residences be conducted to provide residents with information and reassurance. A meeting with representatives of the Task Force was held on 17 September 2001 in Lower Manhattan. The Task Force representatives specified areas around Ground Zero that were of greatest concern.

A small-scale monitoring survey of two residential buildings was conducted. One of the buildings was on Warren Street four blocks north of Ground Zero, and the second building was on South End Avenue, close to Ground Zero, to the southwest of the World Trade Center. The Warren Street location was considered to have been exposed to lower concentrations of dust than those at the South End Avenue location. The locations of the two buildings are shown in Figure 1. The purpose of the survey was to determine the levels of PCBs, PCDDs, PCDFs, metals, and asbestos inside the buildings, and whether specialized cleaning techniques would be required prior to re-occupancy. The aim of this report is to present the results of the survey and to make recommendations on the basis of these results.

Figure 1. Location of High and Low Dust Exposure Apartment Buildings.

2.0 STUDY DESIGN AND SAMPLING STRATEGY

The buildings were selected to provide one example of a residential building that had apparently incurred a low exposure to the dust, and one example of a residential building that had obviously incurred a high exposure to the dust. The selection was based on the proximity of the building to Ground Zero, the degree to which the building was shielded from Ground Zero by other buildings, and the external integrity of the building.

2.1 The Low Exposure Building

The low exposure 7-story building had been fully renovated and modernized into spacious luxury apartments, with one apartment per floor. It is located on Warren Street, four blocks north of Ground Zero; numerous low-rise and high-rise buildings are found between this location and Ground Zero. The building showed no signs of external damage. All of the windows are intact, most of which are on the north side facing away from Ground Zero. The 5th Floor penthouse apartment comprises three levels -- the top one being a loft with an exit onto the rooftop. The building superintendent reported that a layer of dust had coated the stairwells and staircase several days before the sampling, but that these areas had already been cleaned. No other part of the building had been cleaned. The apartments on the 2nd and 5th Floors were selected for the study. The building superintendent reported that these apartments were normally cleaned regularly. It was concluded that the visible dust (Figure 2) on table tops near the window and on the inside window sills likely originated from the dust cloud generated by the destruction of the World Trade Center buildings.

2.2 The High Exposure Building

As shown in Figure 1, the high exposure 30-story apartment building is situated on South End Avenue, close to and southwest of Ground Zero. Windows of several apartments on the upper levels had been broken, but the building showed no other signs of external damage. This building was selected for study because it appeared to be the nearest one to Ground Zero that had electrical power available for operation of air sampling pumps. Apartment 10D on the

Figure 2. Dust Deposited on Furniture in Low (top) and High (bottom) Exposure Apartment Buildings.

east side of the 10th Floor was selected as representative of an apartment that had sustained window damage, was impacted by the dust cloud, and was in close proximity to the destruction of the World Trade Center Complex. The apartment consisted of a living room, dining room, kitchen, den, two bathrooms, and a master bedroom. One of the windows of the master bedroom had been damaged by a projectile that had passed through the bedroom and penetrated the wall of a clothes closet on the opposite side of the room. The bed and carpets were covered with dust and broken glass. The view of Ground Zero from the window was completely unobstructed. Heavy dust deposits were visible on all horizontal surfaces of tables, cupboards, and counters. Loose dust and debris were piled up to approximately a 45-degree angle on the exterior window ledges of the apartment.

2.3 Sampling Strategy

The overall sampling strategy consisted of collecting air samples, surface dust and debris samples, and exterior dust and debris samples to determine the presence of asbestos, as well as surface wipe and exterior dust and debris samples to determine the presence of inorganic metals, polychlorinated dibenzo-p-dioxins (PCDDs), polychlorinated dibenzofurans (PCDFs), and polychlorinated biphenyls (PCBs). Table 1 shows the numbers of samples collected and analyzed.

TABLE 1. TYPE AND DISTRIBUTION OF SAMPLES COLLECTED AND ANALYZED

Location	PCDD/PCDF/PCBs			Inorganic Metals			Asbestos		
	Surface Wipe	Surface Dust	Bulk Dust	Surface Wipe	Surface Dust	Bulk Dust	Air	Surface Dust	Exterior Dust
45 Warren Street 2nd Floor	2	0	0	2	0	0	3	2	0
45 Warren Street 5th Floor	2	0	0	2	0	0	3	2	0
45 Warren Street Roof	0	0	1	0	0	1	1	0	1
Church Street South of Duane Automobile Roof	0	0	0	0	0	0	0	0	1
250 South End Ave. Apartment 10D Interior	1	1	0	0	1	1	5	2	0
250 South End Ave. Apartment 10D Exterior	0	0	0	0	0	0	1	0	0
250 South End Ave. Apartment 11D Exterior Window Sill	0	0	1	0	0	0	0	0	1
250 South End Ave. Ground Level Courtyard	0	0	0	0	0	0	0	0	1
TOTAL[a]	5	1	2	4	1	2	13	6	4

[a] Excludes quality assurance field blanks.

3.0 PCDDs, PCDFs, AND PCBs

3.1 Collection

3.1.1 Surface Wipe

Isopropanol-moistened 3-inch by 3-inch cotton gauze pads were used to collect surface-wipe samples from table tops and other furniture. The gauze pad was held with a gloved hand (non-linear polyethylene-type glove). The surface was wiped using successive swaths first in one direction, then in a second direction perpendicular to the first. Multiple gauze pads were used as necessary depending on the surface dust loading. The gauze pad sample was then placed in a clean glass sample container equipped with a Teflon-lined lid. The sample area was measured and recorded.

3.1.2 Surface Dust

A new stiff bristle toothbrush was used to collect dust samples from furniture such as table tops and other furniture with a hard surface. The dust was swept into a pile and collected using a scoop constructed of paper. The dust was then placed in a clean 50-ml polyethylene centrifuge tube with a screw-cap lid. The sample area was measured and recorded.

3.1.3 Bulk Dust

Bulk dust samples were collected from exterior surfaces (including a window ledge and a roof top) with heavy deposits of dust. The dust was placed in either a clean zip-lock plastic bag or 50-ml plastic centrifuge tube.

3.2 Analysis

3.2.1 Surface Wipe

The samples were prepared and analyzed to determine the presence of tetra- through octa-chlorinated dibenzo-p-dioxins and dibenzofurans and the respective 2,3,7,8-substituted isomers using high-resolution gas chromatography/high-resolution mass spectroscopy (HRGC/HRMS) in

accordance with EPA SW-846 Method 8290. The samples for PCBs as Aroclors (PCB-1016, PCB-1221, PCB-1232, PCB-1242, PCB-1248, PCB-1254, and PCB-1260) were prepared and analyzed using gas chromatography with electron capture detection in accordance with EPA SW-846 Method 8082.

3.2.2 Surface and Bulk Dust

The samples were prepared and analyzed to determine the presence of PCDDs, PCDFs, and PCBs as described in Section 3.2.1.

3.3 Results

3.3.1 Surface Wipe

Table 2 presents concentrations of PCDDs/PCDFs (expressed as 2,3,7,8-Tetrachlorobenzo-p-dioxin Equivalents[1]) and PCBs. The concentrations of 2,3,7,8-TCDD Equivalents ranged from 0.0012 to 0.088 ng/m^2. By comparison, the concentrations are numerically lower than the background concentrations (0.05-0.29 ng/m^2) measured in commercial office buildings in the United States (Kominsky and Kwoka, 1989). The concentrations are also significantly less than the guideline (25 ng/m^2 2,3,7,8-TCDD Equivalents) recommended by the National Academy of Sciences, Subcommittee on Dioxin (NAS 1988). All PCB concentrations were below the analytical limit of detection (<0.10 µg/m^2) and are thus within comparative background levels (Kominsky et. al, 1989).

The PCDDs and PCDFs were likely produced during the combustion of PCB-containing materials and chlorinated compounds such as PVC plastics. Historically, PCBs were used in dielectric fluids in electrical transformers and capacitors (e.g., fluorescent light ballasts and video

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[1] The potential toxicity of mixtures of PCDDs and PCDFs in environmental samples is estimated by converting the respective concentrations of PCDDs and PCDFs to 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8-TCDD Equivalents) (EPA 1989). This mathematical conversion represents the estimated amount of 2,3,7,8-tetrachlorodibenzo-p-dioxin (i.e., the 2,3,7,8-TCDD isomer) that would have to be present to exhibit the same toxicity as the measured quantities of each of the various PCDDs and PCDFs that are present in a sample.

display terminals, hydraulic fluids, and heat transfer fluids) as well as plasticizers in paints, caulking, and adhesives.

3.3.2 Surface Dust and Bulk Samples

Table 3 presents the concentrations of PCDDs/PCDFs (expressed as 2,3,7,8-TCDD Equivalents) and PCBs in surface wipe and dust bulk samples, respectively. The concentrations ranged from 33 to 260 ng/kg, which are significantly lower than cleanup guidelines for soil/dust (5,000 to 7,000 ng/kg) recommended by the U.S. Department of Health and Human Services, Centers for Disease Control and Prevention (CDC 1984). The mass-to-mass concentration (54 ng/kg) of 2,3,7,8-TCDD Equivalents in the surface dust sample was converted to a mass per area concentration (0.47 ng/m^2) based on a sample area of 0.529 m^2, which is also similar to the upper limit background (0.29 ng/m^2) and below the NAS guideline (25 ng/m^2).

TABLE 2. CONCENTRATION OF 2,3,7,8-TCDD EQUIVALENTS (I/TEF-89) AND PCB AROCLORS IN SURFACE WIPE SAMPLES OBTAINED FROM HORIZONTAL SURFACES IN APARTMENTS

Sample No.	Sample Location	Sample Description	2378-TCDD Equiv., ng/m^2	PCBs,[a] µg/m^2
250SEA10D-DF1	250 South End Ave, Location 1, Site 1	Top of entertainment center & dining room table (sample area = 1.04 m^2)	0.038	ND (<0.10)
45WAR2-DF1	45 Warren Street, Location 1, Site 1	Top of table (sample area = 1.08 m^2)	0.026	ND (<0.10)
45WAR2-DF2	45 Warren Street, Location 1, Site 1	Bench window ledge (sample area = 0.372 m^2)	0.088	ND (<0.10)
45WAR5-DF2	45 Warren Street, Location 1, Site 2	Top of table (sample area = 0.932 m^2)	0.0012	ND (<0.10)
45WAR5-DF1	45 Warren Street, Location 1, Site 2	Top of table (sample area = 1.022 m^2)	0.012	ND (<0.10)
45WAR2-DF3	45 Warren Street, Location 1, Site 1	Field Blank	0.0	ND (<0.10)

[a] Aroclors 1016, 1221, 1232, 1242, 1248, 1254, and 1260 were not present above the reported analytical limit of detection.

TABLE 3. CONCENTRATION OF 2,3,7,8-TCDD EQUIVALENTS (I/TEF-89) AND PCB AROCLORS IN DUST OBTAINED FROM APARTMENTS

Sample No.	Sample Location	Sample Description	2378-TCDD Equiv., ng/kg	PCB-1260,[b] mg/kg
250SEA10D-DF2	250 South End Ave, Location 1, Site 1	Dust from surface of chest (sample area 0.529 m^2)	54[a]	0.16[c]
250SEA-WL-BD1	250 South End Ave, Location 1, Site 1	Dust from exterior window ledge at east elevation	260	0.35
250SEA-R-BD2	45 Warren Street	Dust from rooftop	33	0.23

[a] Equivalent to a surface concentration of 0.47 ng/m^2 based on a sample area of 0.529 m^2.

[b] Aroclors 1016, 1221, 1232, 1242, 1248, and 1254 were not present above the reported analytical limit of detection.

[c] Equivalent to a surface concentration of 0.66 µg/m^2 based on a sample area of 0.529 m^2.

4.0 INORGANIC METALS

4.1 Collection

4.1.1 Surface Wipe

Disposable wipes were used to collect surface wipe samples from furniture with hard surfaces such as table tops. Sampling was conducted in accordance with the procedure specified in Appendix 13.1, "Wipe Sampling for Settled Lead-Contaminated Dust" of the HUD Guidelines for the Evaluation and Control of Lead-Based Paint Hazards in Housing (HUD 1995). The sample area was measured and recorded.

4.1.2 Surface Dust

A new stiff bristle toothbrush was used to collect surface dust samples from table tops and other furniture with hard surfaces. The dust was swept into a pile and then collected using a scoop constructed of paper. The dust was then placed in a clean 50-ml polyethylene centrifuge tube with a screw-cap lid. The sample area was measured and recorded.

4.1.3 Bulk Dust

Bulk dust samples were collected from exterior surfaces (including a window ledge and a roof top) showing heavy deposits of dust. The dust was placed in either a clean zip-lock plastic bag or 50-ml plastic centrifuge tube.

4.2 Analysis

4.2.1 Surface Wipe

The samples were prepared in accordance with EPA SW-846 Method 3050 and analyzed to determine the presence of 22 metals (excluding mercury). The samples were analyzed in accordance with EPA SW-846 Method 6010 using inductively coupled plasma atomic absorption spectrometry (ICP-AES). The samples for mercury were prepared and analyzed for mercury in accordance with EPA SW-846 Method 7471.

4.2.2 Surface Dust and Bulk Samples

The samples were prepared and analyzed to determine the presence of mercury and the other 22 metals as described in Section 4.2.1.

4.3 Results of Surface Dust and Bulk Samples

The analyses of 23 metals present in the dust deposited in the "high" and "low" exposure apartment buildings are presented in Tables 4 and 5. These tables present surface wipe and bulk dust sample analyses.

The concentrations of metals with the highest potential chronic toxicity (such as arsenic, beryllium, cadmium, chromium, lead, mercury, and nickel) are relatively low or are not present above the analytical limit of detection. Regarding lead, a dust-lead hazard is defined as a surface in a residential dwelling or child-occupied facility that contains a mass-per-area concentration of lead equal to or exceeding 40 $\mu g/ft^2$ on floors or 250 $\mu g/ft^2$ on interior window sills based on wipe samples (Federal Register, Vol. 66, No. 4, January 5, 2001). By comparison, lead concentrations measured in the apartments ranged from 14 to 30 $\mu g/ft^2$.

Calcium represented approximately 9 to 19 percent (9.1-190,000 $\mu g/g$) of the metals present in the dust. Mineral wool in the Trade Center Towers contained a large percentage of calcium. Mineral wool made up approximately 60 percent of the fireproofing. Calcium oxide (lime) is a primary component of cement, calcium sulfate (gypsum) is the primary component of wallboard (drywall), and calcium is a primary component of mineral wool (fireproofing). Because calcium oxide is alkaline and reacts with moisture to form calcium hydroxide, exposure to the dust can irritate the eyes, mucous membranes, and/or skin.

TABLE 4. CONCENTRATIONS OF METALS IN WIPE SAMPLES OBTAINED FROM FURNITURE

	"Low Dust Building" 45 Warren Street				Field Blank	"High Dust Building" 250 South End Avenue
	45WAR2PB1	45WAR2PB2	45WAR5PB1	45WAR5PB2	45WAR5PB3[b]	250SEA10DPB1[c]
Metal	Concentrations - µg/ft²					
Aluminum	475	777	1,007	30	57	1,745
Antimony	33	35	18	20	120	2
Arsenic	ND	ND	ND	ND	ND	ND
Barium	13	19	16	ND	ND	25
Beryllium	ND[a]	ND	ND	ND	ND	ND
Cadmium	ND	ND	ND	ND	ND	1
Calcium	4,754	7,769	874	302	690	22,907
Chromium	3	4	4	ND	ND	12
Cobalt	1	2	1	ND	ND	1
Copper	7	10	10	2	ND	17
Iron	350	551	519	22	ND	1,036
Lead	25	30	14	14	ND	24
Magnesium	676	977	1,185	49	200	1,963
Manganese	23	38	47	1	ND	68
Mercury	9	0.04	0.02	ND	ND	ND
Nickel	2	2	1	1	ND	3
Potassium	108	183	207	36	38	355
Selenium	ND	ND	ND	ND	ND	ND
Silver	ND	ND	ND	ND	ND	ND
Sodium	275	426	267	133	590	464
Thallium	ND	ND	ND	ND	ND	ND
Vanadium	1	1	1	ND	ND	2
Zinc	48	75	89	6	ND	183

[a] Denotes the concentration was below the analytical limit of detection.
[b] Micrograms of metal per sample.
[c] Surface dust.

TABLE 5. CONCENTRATIONS OF METALS IN DUST SAMPLES

Metal	"High Dust Building" 250 South End Ave., 10th Floor Exterior Window Ledge (250SEABD2)	"High Dust Building" 250 South End Ave., 10th Floor Table Top (250SEA10DPB1)	"Low Dust Building" 45 Warren Street Roof Top (45WARBD1)
	Concentration - µg/g (ppm)		
Aluminum	22,000	6,900	31,000
Antimony	24	9.0	40
Arsenic	ND[a]	ND	11
Barium	210	100	500
Beryllium	2.1	0.6	3.6
Cadmium	ND	4.0	ND
Calcium	190,000	91,000	170,000
Chromium	75	47	110
Cobalt	5.9	2.7	13
Copper	70	67	140
Iron	8,600	4,100	12,000
Lead	220	96	140
Magnesium	24,000	7,800	40,000
Manganese	810	270	1,600
Mercury	ND	0.38	ND
Nickel	22	13	33
Potassium	2,700	1,400	6,400
Selenium	ND	ND	ND
Silver	ND	1.2	ND
Sodium	3,500	1,800	3,400
Thallium	ND	ND	ND
Vanadium	23	9.7	31
Zinc	820	730	1,600

[a] Denotes that the concentration is below the analytical limit of detection.

5.0 ASBESTOS MEASUREMENTS

5.1 Asbestos in Passive Air Samples

5.1.1 Sample Collection

Air samples were collected using 25-mm-diameter 3-piece plastic cassettes with short cowls. Each cassette contained a 25-mm-diameter, 0.45-µm porosity, mixed esters of cellulose (MCE) filter, with a 5.0-µm MCE back-up filter and a cellulose support pad. Each sampler operated at a flow rate of approximately 9 liters/minute and was calibrated at the start and finish of sampling. All air sampling was conducted under passive conditions, and no air conditioning or ventilation systems were operating at the time of sampling. Considerable amounts of settled dust and debris were present on all horizontal surfaces in each of the apartments where the indoor samples were collected. Disturbance of this surface dust was minimized, personnel were near the air samplers only to monitor their operation, and dust and debris samples were collected with a minimum of disturbance.

At 45 Warren Street, three air samplers were positioned in the 2nd Floor apartment and three in the 5th Floor apartment. An exterior sample was also collected on the roof outside the 5th Floor loft. Each of these samplers operated over a period of time sufficient to collect the particulate material from approximately 1200 liters of air. An open field blank and a closed field blank were included with this set of air samples.

At 250 South End Avenue, five samples were collected in Apartment 10D, and one exterior sample was collected by positioning the cassette outside a sliding window. An open field blank and a closed field blank were included with this set of air samples. The intent was to collect particulate material from approximately 1200 liters of air, but the sample collection had to be terminated prematurely because the filters were becoming overloaded.

5.1.2 Analysis

The sample filters from 45 Warren Street were prepared and analyzed by transmission electron microscopy (TEM) using the direct-transfer method ISO10312. An initial attempt to prepare TEM specimens by ISO10312 from the air sample filters from 250 South End Avenue

was unsuccessful because of the high particulate loadings on the filters. Examination of the unsatisfactory TEM specimens prepared from these filters indicated that much of the material on the filters was gypsum and cement dust. It was found that the gypsum and the water-soluble components of the cement dust could be removed from the surfaces of the filters by a water extraction treatment. After this treatment, specimens suitable for TEM analysis for asbestos were obtained by using the preparation procedures of ISO10312. TEM data recorded according to ISO10312 allows for results to be compared with known TEM and phase contrast microscopy (PCM) exposure criteria. The TEM fiber counting data was interpreted to derive the concentrations of asbestos structures greater than 0.5 μm, asbestos fibers and bundles longer than 5 μm, and PCM-equivalent asbestos fibers and bundles (fibers and bundles longer than 5 μm with widths greater than 0.25 μm).

5.1.3 Results

Tables 6 through 13 present the results of the TEM analyses for asbestos in the air samples collected at 45 Warren Street. The maximum concentration of chrysotile structures greater than 0.5 μm observed under the passive conditions of the air sampling indoors was 0.12 structure/mL, with an upper 95% confidence limit of 0.16 structure/mL. The maximum mean airborne concentration of chrysotile fibers longer than 5 μm observed under the passive conditions of the air sampling indoors was 0.018 fiber/mL, with an upper 95% confidence limit of 0.034 fiber/mL. The maximum mean airborne concentration of PCM-equivalent chrysotile fibers observed under the passive conditions of the air sampling indoors was 0.010 fiber/mL, with an upper 95% confidence limit of 0.023 fiber/mL. No amphibole fibers were detected in any of these indoor samples. Only one asbestos fiber was detected in the sample collected outdoors. This fiber was a chrysotile fiber longer than 5 μm (but too narrow to be PCM-equivalent), and corresponded to an upper 95% confidence limit of 0.012 structure/mL. No asbestos fibers of any size were detected on the open field blank, corresponding to an upper 95% confidence limit of 0.007 structure/mL for an assumed air volume of 1200 liters. It must be appreciated that these are the airborne asbestos concentrations measured in samples collected under passive conditions and that airborne asbestos concentrations would become

TABLE 6. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-2-A1 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	0.10 ND 0.10	0.075 - 0.14 0 - 0.007 0.075 - 0.14	0.00209 0.00209 0.00209	316 0 316	1190 1190 1190	49 0 49
Sample 45WAR-2-A2 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	0.12 ND 0.12	0.093 - 0.16 0 - 0.007 0.093 - 0.16	0.00212 0.00212 0.00212	376 0 376	1176 1176 1176	58 0 58
Sample 45WAR-2-A3 9/18/01 2nd Floor Master Bedroom	Chrysotile Amphibole Total	0.085 ND 0.085	0.061 - 0.12 0 - 0.006 0.061 - 0.12	0.00197 0.00197 0.00197	279 0 279	1269 1269 1269	43 0 43

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)

TABLE 7. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

FIBERS AND BUNDLES LONGER THAN 5 MICROMETERS

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-2-A1 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	0.010 ND 0.010	0.003 - 0.025 0 - 0.007 0.003 - 0.025	0.00210 0.00210 0.00210	32.4 0 32.4	1190 1190 1190	5 0 5
Sample 45WAR-2-A2 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	0.011 ND 0.011	0.003 - 0.025 0 - 0.007 0.003 - 0.025	0.00211 0.00211 0.00211	32.2 0 32.2	1176 1176 1176	5 0 5
Sample 45WAR-2-A3 9/18/01 2nd Floor Master Bedroom	Chrysotile Amphibole Total	0.018 ND 0.018	0.008 - 0.034 0 - 0.006 0.008 - 0.034	0.00196 0.00196 0.00196	58.1 0 58.1	1269 1269 1269	9 0 9

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined
ND - No Countable Fibers Detected
NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 8. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

PCM-EQUIVALENT FIBERS AND BUNDLES
(Length >5 micrometers; Width >0.25 micrometer; Aspect Ratio ≥3:1)

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-2-A1 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	NSS ND NSS	0 - 0.012 0 - 0.007 0 - 0.012	0.00210 0.00210 0.00210	6.5 0 6.5	1190 1190 1190	1 0 1
Sample 45WAR-2-A2 9/18/01 2nd Floor Living Room	Chrysotile Amphibole Total	ND ND ND	0 - 0.007 0 - 0.007 0 - 0.007	0.00211 0.00211 0.00211	0 0 0	1176 1176 1176	0 0 0
Sample 45WAR-2-A3 9/18/01 2nd Floor Master Bedroom	Chrysotile Amphibole Total	0.010 ND 0.010	0.003 - 0.023 0 - 0.006 0.003 - 0.023	0.00196 0.00196 0.00196	32.3 0 32.3	1269 1269 1269	5 0 5

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined
ND - No Countable Fibers Detected
NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 9. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-2-A4 9/18/01 2nd Floor Open Blank	Chrysotile Amphibole Total	ND ND ND	0 - 0.007 0 - 0.007 0 - 0.007	0.00206 0.00206 0.00206	0 0 0	1200** 1200** 1200**	0 0 0

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)
** - Assumed air volume for calculation

TABLE 10. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-5-A1 9/18/01 5th Floor Living Room	Chrysotile Amphibole Total	0.046 ND 0.046	0.028 - 0.069 0 - 0.007 0.028 - 0.069	0.00207 0.00207 0.00207	142 0 142	1201 1201 1201	22 0 22
Sample 45WAR-5-A2 9/18/01 5th Floor Dining Room	Chrysotile Amphibole Total	0.046 ND 0.046	0.028 - 0.071 0 - 0.007 0.028 - 0.071	0.00221 0.00221 0.00221	141 0 141	1170 1170 1170	21 0 21
Sample 45WAR-5-A3 9/18/01 5th Floor Bedroom Level	Chrysotile Amphibole Total	0.051 ND 0.051	0.033 - 0.076 0 - 0.007 0.033 - 0.076	0.00204 0.00204 0.00204	162 0 162	1226 1226 1226	25 0 25

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)

TABLE 11. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

FIBERS AND BUNDLES LONGER THAN 5 MICROMETERS

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-5-A1 9/18/01 5th Floor Living Room	Chrysotile Amphibole Total	0.008 ND 0.008	0.002 - 0.019 0 - 0.005 0.002 - 0.019	0.00155 0.00155 0.00155	24.2 0 24.2	1201 1201 1201	5 0 5
Sample 45WAR-5-A2 9/18/01 5th Floor Dining Room	Chrysotile Amphibole Total	0.013 ND 0.013	0.004 - 0.029 0 - 0.007 0.004 - 0.029	0.00221 0.00221 0.00221	40.2 0 40.2	1170 1170 1170	6 0 6
Sample 45WAR-5-A3 9/18/01 5th Floor Bedroom Level	Chrysotile Amphibole Total	0.008 ND 0.008	0.002 - 0.018 0 - 0.005 0.002 - 0.018	0.00153 0.00153 0.00153	24.4 0 24.4	1226 1226 1226	5 0 5

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined
ND - No Countable Fibers Detected
NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 12. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

PCM-EQUIVALENT FIBERS AND BUNDLES
(Length >5 micrometers; Width >0.25 micrometer; Aspect Ratio ≥3:1)

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-5-A1 9/18/01 5th Floor Living Room	Chrysotile Amphibole Total	NSS ND NSS	0 - 0.009 0 - 0.005 0 - 0.009	0.00155 0.00155 0.00155	4.8 0 4.8	1201 1201 1201	1 0 1
Sample 45WAR-5-A2 9/18/01 5th Floor Dining Room	Chrysotile Amphibole Total	NSS ND NSS	0 - 0.013 0 - 0.007 0 - 0.013	0.00221 0.00221 0.00221	6.7 0 6.7	1170 1170 1170	1 0 1
Sample 45WAR-5-A3 9/18/01 5th Floor Bedroom Level	Chrysotile Amphibole Total	ND ND ND	0 - 0.005 0 - 0.005 0 - 0.005	0.00153 0.00153 0.00153	0 0 0	1226 1226 1226	0 0 0

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined
ND - No Countable Fibers Detected
NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 13. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

45 WARREN STREET, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 45WAR-5-A4 9/18/01 5th Floor Roof, Outside Loft	Chrysotile Amphibole Total	NSS ND NSS	0 - 0.012 0 - 0.007 0 - 0.012	0.00210 0.00210 0.00210	6.5 0 6.5	1183 1183 1183	1 0 1
Sample 45WAR-5-A5 9/18/01 5th Floor Open Blank	Chrysotile Amphibole Total	ND ND ND	0 - 0.007 0 - 0.007 0 - 0.007	0.00205 0.00205 0.00205	0 0 0	1200** 1200** 1200**	0 0 0

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)
** - Assumed air volume for calculation

significantly elevated if the asbestos-containing dust and debris on the surfaces was disturbed by routine methods of dry dusting and vacuuming.

The results of the TEM analyses for asbestos in the air samples collected at 250 South End Avenue are shown in Tables 14 through 17. Because these samples were heavily loaded with large numbers of chrysotile fibers, the counting of structures greater than 0.5 µm had to be terminated after TEM examination of only one grid opening for each of the indoor samples. Examination of the TEM specimens for asbestos structures greater than 5 µm was continued. The maximum concentration of chrysotile structures greater than 0.5 µm was estimated to be 3.74 structures/mL, with an upper 95% confidence limit of 4.53 structures/mL, based on the TEM examination of only one grid opening. The maximum concentration of chrysotile fibers longer than 5 µm was 0.29 fiber/mL, with an upper 95% confidence limit of 0.35 fiber/mL. In Sample 250SEA-10D-A5, two fibers of richterite asbestos (longer than 5 µm) were detected, corresponding to an upper 95% confidence limit for the airborne richterite asbestos concentration of 0.030 fiber/mL (fibers longer than 5 µm). During the limited TEM examination of Sample 250SEA-10D-A5 for asbestos structures greater than 0.5 µm, one amosite fiber (longer than 5 µm) was detected, corresponding to an estimated upper 95% confidence limit for airborne amosite of 0.23 structure/mL. The maximum mean airborne concentration of PCM-equivalent chrysotile fibers observed under the passive conditions of the air sampling indoors was 0.075 fiber/mL, and the maximum upper 95% confidence limit was 0.12 fiber/mL. The two PCM-equivalent amphibole fibers (richterite asbestos) detected correspond to an upper 95% confidence limit of 0.030 fiber/mL. The maximum mean concentration of PCM-equivalent asbestos fibers and bundles (chrysotile + amphibole) was found to be 0.081 fiber/mL in Sample 250SEA-10D-A5, with an upper 95% confidence limit of 0.13 fiber/mL.

Chrysotile was detected in the exterior sample collected outside the apartment window at 250 South End Avenue. The concentration of chrysotile structures greater than 0.5 µm was 0.22 structure/mL, with an upper 95% confidence limit of 0.27 structure/mL; the mean concentration of chrysotile fibers longer than 5 µm was 0.022 fiber/mL, with an upper 95% confidence limit of 0.043 fiber/mL. In this exterior sample, one fiber of amosite (shorter than 5 µm) was detected, corresponding to an upper 95% confidence limit for the airborne amosite

TABLE 14. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

250 SOUTH END AVENUE, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER - ESTIMATES BASED ON 1 GRID OPENING ONLY

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 250SEA-10D-A1 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	3.74 ND 3.74	3.07 - 4.53 0 - 0.11 3.07 - 4.53	0.0347 0.0347 0.0347	10620 0 10620	1092 1092 1092	108 0 108
Sample 250SEA-10D-A2 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	3.01 ND 3.01	2.39 - 3.75 0 - 0.12 2.39 - 3.75	0.0372 0.0372 0.0372	7832 0 7832	1001 1001 1001	81 0 81
Sample 250SEA-10D-A3 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	2.56 ND 2.56	1.98 - 3.26 0 - 0.12 1.98 - 3.26	0.0388 0.0388 0.0388	6277 0 6277	944 944 944	66 0 66
Sample 250SEA-10D-A4 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	2.45 ND 2.45	1.89 - 3.13 0 - 0.12 1.89 - 3.13	0.0377 0.0377 0.0377	6285 0 6285	987 987 987	65 0 65
Sample 250SEA-10D-A5 9/18/01 Apartment 10D Bedroom	Chrysotile Amphibole Total	3.01 NSS 3.05	2.36 - 3.78 0 - 0.23 2.39 - 3.83	0.0407 0.0407 0.0407	7155 97 7252	915 915 915	74 1 75

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)

TABLE 15. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

250 SOUTH END AVENUE, NEW YORK CITY

FIBERS AND BUNDLES LONGER THAN 5 MICROMETERS

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 250SEA-10D-A1 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	0.22 ND 0.22	0.16 - 0.28 0 - 0.011 0.16 - 0.28	0.00348 0.00348 0.00348	611 0 611	1092 1092 1092	62 0 62
Sample 250SEA-10D-A2 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	0.23 ND 0.23	0.17 - 0.30 0 - 0.012 0.17 - 0.30	0.00376 0.00376 0.00376	597 0 597	1001 1001 1001	61 0 61
Sample 250SEA-10D-A3 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	0.16 ND 0.16	0.12 - 0.22 0 - 0.008 0.12 - 0.22	0.00264 0.00264 0.00264	402 0 402	944 944 944	62 0 62
Sample 250SEA-10D-A4 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	0.29 ND 0.29	0.23 - 0.35 0 - 0.008 0.23 - 0.35	0.00251 0.00251 0.00251	746 0 746	987 987 987	116 0 116
Sample 250SEA-10D-A5 9/18/01 Apartment 10D Bedroom	Chrysotile Amphibole Total	0.28 NSS 0.28	0.21 - 0.36 0 - 0.030 0.22 - 0.36	0.00407 0.00407 0.00407	658 19.3 677	915 915 915	68 2 70

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined

ND - No Countable Fibers Detected

NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 16. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

250 SOUTH END AVENUE, NEW YORK CITY

PCM-EQUIVALENT FIBERS AND BUNDLES
(Length >5 micrometers; Width >0.25 micrometer; Aspect Ratio ≥3:1)

Sample Description	Fiber Type	Fiber Concentration, Fibers/mL			Fibers per Square Millimeter	Volume of Air Sampled Liters	Number of Fibers Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 250SEA-10D-A1 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	0.063 ND 0.063	0.037 - 0.099 0 - 0.011 0.037 - 0.099	0.00348 0.00348 0.00348	178 0 178	1092 1092 1092	18 0 18
Sample 250SEA-10D-A2 9/18/01 Apartment 10D Den	Chrysotile Amphibole Total	0.060 ND 0.060	0.034 - 0.098 0 - 0.012 0.034 - 0.098	0.00376 0.00376 0.00376	157 0 157	1001 1001 1001	16 0 16
Sample 250SEA-10D-A3 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	0.048 ND 0.048	0.028 - 0.076 0 - 0.008 0.028 - 0.076	0.00264 0.00264 0.00264	117 0 117	944 944 944	18 0 18
Sample 250SEA-10D-A4 9/18/01 Apartment 10D Living Room	Chrysotile Amphibole Total	0.075 ND 0.075	0.050 - 0.11 0 - 0.008 0.050 - 0.11	0.00251 0.00251 0.00251	193 0 193	987 987 987	30 0 30
Sample 250SEA-10D-A5 9/18/01 Apartment 10D Bedroom	Chrysotile Amphibole Total	0.073 NSS 0.081	0.043 - 0.12 0 - 0.030 0.043 - 0.13	0.00407 0.00407 0.00407	174 19.3 193	915 915 915	18 2 20

* - No mean value is reported when fewer than 4 countable fibers were detected in the portion of sample examined
ND - No Countable Fibers Detected
NSS - Not Statistically Significant (1 to 3 countable fibers detected)

TABLE 17. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR AIRBORNE ASBESTOS

250 SOUTH END AVENUE, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample Description	Fiber Type	Structure Concentration, Structures/mL			Structures per Square Millimeter	Volume of Air Sampled Liters	Number of Structures Counted
		Mean *	95% Confidence Interval	Analytical Sensitivity			
Sample 250SEA-10D-A6 9/18/01 Apartment 10D Outside L R Window	Chrysotile Amphibole Total	0.22 NSS 0.22	0.17 - 0.27 0 - 0.016 0.17 - 0.28	0.00270 0.00270 0.00270	548 6.8 554	977 977 977	80 1 81
Sample 250SEA-10D-A7 9/18/01 Apartment 10D Open Blank	Chrysotile Amphibole Total	ND ND ND	0 - 0.007 0 - 0.007 0 - 0.007	0.00207 0.00207 0.00207	0 0 0	1200** 1200** 1200**	0 0 0

* - No mean value is reported when fewer than 4 countable structures were detected in the portion of sample examined
ND - No Countable Structures Detected
NSS - Not Statistically Significant (1 to 3 countable structures detected)
** - Assumed air volume for calculation

asbestos concentration of 0.016 structure/mL. Some contamination of the exterior air sample by chrysotile might have been expected, given that asbestos-containing debris from the collapse of the buildings had accumulated on the exterior window ledges to the maximum depth possible. No asbestos structures of any size were detected on the open field blank.

All horizontal surfaces of Apartment 10D were covered by a thick layer of dust and debris that contained asbestos. It is important to take into account that the indoor air concentration results reported were obtained under passive sampling conditions with no active ventilation and minimum disturbance of the surface dust and debris. Disturbance of the dust by routine methods of dry dusting and vacuuming would significantly increase the airborne asbestos concentrations in the apartment. Based on the amount of visible dust and debris on surfaces in the apartment, the airborne asbestos could increase by orders of magnitude.

5.2 Dust and Debris Samples Collected from Surfaces in Buildings

5.2.1 Sample Collection

At 45 Warren Street, dust and debris were visible on surfaces in the apartments. A wet non-woven cloth was used to collect dust and debris samples in accordance with ASTM D6480-99.

At 250 South End Avenue, a window had been broken and the hard surfaces of furniture were coated with a layer of dust and debris sufficiently thick that it could be swept up with a brush. A new toothbrush was first used to remove dust and debris from a known area of the surface, and the collected material was transferred to a plastic container, after which a wet non-woven cloth was used to collect the visible dust and debris that still remained on the surface. Sampling was conducted in accordance with ASTM D6480-99. Each wet cloth was stored in a plastic container.

5.2.2 Sample Analysis

The wipe samples were analyzed according to ASTM D6480-99. For each of the two dust and debris samples collected using a toothbrush at the 250 South End Avenue location, a known weight of the dust and debris sample was dispersed in 100 mL of filtered distilled water.

The TEM specimens from these suspensions were then prepared according to ASTM D6480-99 in all subsequent steps.

5.2.3 Results

The results for the samples collected at 45 Warren Street are shown in Tables C18 and C19. Table C18 shows the results for asbestos structures greater than 0.5 µm, and Table C19 shows the results for asbestos fibers and bundles longer than 5 µm. In these samples, surface chrysotile concentrations up to 470,000 structures/cm^2 were observed, of which up to 79,000 fibers/cm^2 were fibers and bundles longer than 5 µm. Only one amosite fiber, equivalent to a surface concentration of 2200 structures/cm^2, was observed.

During preparation of the specimens from the 5th Floor at 45 Warren Street, vermiculite particles in the aqueous suspension were found to be visible to the unaided eye.

The results for the samples collected at 250 South End Avenue are shown in Tables 20 and 21. Table 20 shows the results for asbestos structures longer than 0.5 µm, and Table 21 shows the results for asbestos fibers and bundles longer than 5 µm. There are two results for each of the two surfaces sampled. The first result is for the dust and debris collected using a toothbrush. It should be noted that the collection areas specified are calculated from the actual area sampled multiplied by the proportion of the total sample analyzed. The second result in each location is for the follow-up wipe sample, and the collection area specified is the actual area sampled. For each sample location, the results for the two measurements in the final column of Tables 20 and 21 should be added to obtain the total asbestos concentration on the sampled surface. Surface chrysotile concentrations of up to 990,000 structures/cm^2 were observed, of which up to 46,000 were fibers and bundles longer than 5 µm. No amphibole fibers were detected in these samples.

The results show that the dust and debris that have settled on the surfaces in each of the apartments contain substantial amounts of chrysotile. It is important to recognize that the analytical method used is an indirect-transfer method, and that the results from this method, particularly in the case of chrysotile, do not represent the size distribution of the asbestos-containing particles as they existed on the original surface. The analytical method results in the dispersal of large clusters of chrysotile into individual chrysotile fibers and

TABLE 18. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR ASBESTOS IN DUST AND DEBRIS

45 WARREN STREET, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample	Approximate Collection Area cm^2	Dispersal Volume mL	Volume Filtered mL	Analytical Sensitivity structures/cm^2	Type of Asbestos	Number of Asbestos Structures Detected	Concentration of Asbestos Structures on Surface structures/cm^2
Sample 45WAR-2-D1, 9/18/01 2nd Floor, Living Room Table Near Window Wipe Sample	14710	500	1.0	165	Chrysotile	174	29000
					Amphibole	0	<500
					Total	174	29000
Sample 45WAR-2-D2, 9/18/01 2nd Floor, Living Room Window Sill Wipe Sample	3716	500	0.3	2240	Chrysotile	211	470000
					Amphibole	1	2200
					Total	212	470000
Sample 45WAR-5-D1, 9/18/01 5th Floor, Dining Room Large Dining Table Wipe Sample	13316	500	0.1	1760	Chrysotile	264	460000
					Amphibole	0	<5300
					Total	264	460000
Sample 45WAR-5-D2, 9/18/01 5th Floor, Roof Level Office Green Wooden Chair Wipe Sample	2439	500	1.0	980	Chrysotile	110	110000
					Amphibole	0	<3000
					Total	110	110000

TABLE 19. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR ASBESTOS IN DUST AND DEBRIS

45 WARREN STREET, NEW YORK CITY

FIBERS AND BUNDLES LONGER THAN 5 MICROMETERS

Sample	Approximate Collection Area cm^2	Dispersal Volume mL	Volume Filtered mL	Analytical Sensitivity fibers/cm^2	Type of Asbestos	Number of Asbestos Fibers Detected	Concentration of Asbestos Fibers on Surface fibers/cm^2
Sample 45WAR-2-D1, 9/18/01 2nd Floor, Living Room Table Near Window Wipe Sample	14710	500	1.0	165	Chrysotile	14	2300
					Amphibole	0	<500
					Total	14	2300
Sample 45WAR-2-D2, 9/18/01 2nd Floor, Living Room Window Sill Wipe Sample	3716	500	0.3	2240	Chrysotile	27	60000
					Amphibole	0	<6700
					Total	27	60000
Sample 45WAR-5-D1, 9/18/01 5th Floor, Dining Room Large Dining Table Wipe Sample	13316	500	0.1	1760	Chrysotile	45	79000
					Amphibole	0	<5300
					Total	45	79000
Sample 45WAR-5-D2, 9/18/01 5th Floor, Roof Level Office Green Wooden Chair Wipe Sample	2439	500	1.0	980	Chrysotile	22	22000
					Amphibole	0	<3000
					Total	22	22000

TABLE 20. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR ASBESTOS IN DUST AND DEBRIS

250 SOUTH END AVENUE, NEW YORK CITY

STRUCTURES GREATER THAN 0.5 MICROMETER

Sample	Approximate Collection Area cm^2	Dispersal Volume mL	Volume Filtered mL	Analytical Sensitivity structures/cm^2	Type of Asbestos	Number of Asbestos Structures Detected	Concentration of Asbestos Structures on Surface structures/cm^2
Sample 250SEA-10D-D1, 9/18/01 Apartment 10D, Bedroom Top of Cupboard with Glass Doors (A) Debris Collected by Toothbrush	111	100	1.0	4230	Chrysotile	70	300000
					Amphibole	0	<13000
					Total	70	300000
Sample 250SEA-10D-D1, 9/18/01 Apartment 10D, Bedroom Top of Cupboard with Glass Doors (B) Follow-up Wipe Sample	1677	500	0.3	2400	Chrysotile	111	270000
					Amphibole	0	<7200
					Total	111	270000
Sample 250SEA-10D-D2, 9/18/01 Apartment 10D, Living Room High Boy Side Table (A) Debris Collected by Toothbrush	870	100	0.3	1830	Chrysotile	190	350000
					Amphibole	0	<5500
					Total	190	350000
Sample 250SEA-10D-D2, 9/18/01 Apartment 10D, Living Room High Boy Side Table (B) Follow-up Wipe Sample	2523	500	0.3	3160	Chrysotile	203	640000
					Amphibole	0	<9500
					Total	203	640000

TABLE 21. SUMMARY OF RESULTS OF TRANSMISSION ELECTRON MICROSCOPY ANALYSES FOR ASBESTOS IN DUST AND DEBRIS

250 SOUTH END AVENUE, NEW YORK CITY

FIBERS AND BUNDLES LONGER THAN 5 MICROMETERS

Sample	Approximate Collection Area cm^2	Dispersal Volume mL	Volume Filtered mL	Analytical Sensitivity fibers/cm^2	Type of Asbestos	Number of Asbestos Fibers Detected	Concentration of Asbestos Fibers on Surface fibers/cm^2
Sample 250SEA-10D-D1, 9/18/01 Apartment 10D, Bedroom Top of Cupboard with Glass Doors (A) Debris Collected by Toothbrush	111	100	1.0	4230	Chrysotile	5	21000
					Amphibole	0	<13000
					Total	5	21000
Sample 250SEA-10D-D1, 9/18/01 Apartment 10D, Bedroom Top of Cupboard with Glass Doors (B) Follow-up Wipe Sample	1677	500	0.3	2400	Chrysotile	8	19000
					Amphibole	0	<7200
					Total	8	19000
Sample 250SEA-10D-D2, 9/18/01 Apartment 10D, Living Room High Boy Side Table (A) Debris Collected by Toothbrush	870	100	0.3	1830	Chrysotile	10	18000
					Amphibole	0	<5500
					Total	10	18000
Sample 250SEA-10D-D2, 9/18/01 Apartment 10D, Living Room High Boy Side Table (B) Follow-up Wipe Sample	2523	500	0.3	3160	Chrysotile	9	28000
					Amphibole	0	<9500
					Total	9	28000

bundles, leading to reported chrysotile fiber concentrations higher than would be the case if the material were examined directly on the sampled surface. The magnitude of the increase is a function of fiber length, with long fibers and bundles being less affected than short fibers and bundles. It is also important to consider that if the surface dust and debris are disturbed in such a manner that they become airborne, then elevated airborne asbestos levels will be generated.

5.3 Measurements of Asbestos in Exterior Dust and Debris

5.3.1 Sample Collection

Each sample of exterior dust and debris was collected by removing the material down to the substrate, and transferring the collected material to a clean polyethylene bag. On the north side of the World Trade Center site, one sample was collected from the roof of an automobile parked on Church Street, south of Duane Street, and a second sample was collected from the apartment roof outside the 5th Floor loft at 45 Warren Street. On the southwest side of the World Trade Center site, two samples were collected at 250 South End Avenue. One sample was collected from the exterior window ledge of Apartment 11D, on which material originating from the collapse of buildings had collected to the maximum thickness possible on the ledge. Another sample was collected from the top of a low-level wall in the ground-level courtyard at the back of the building.

5.3.2 Sample Analysis

A gravimetric matrix reduction procedure (ASTM STP 1342) was used to analyze the samples. To ensure that the analyses were representative of the collected materials, a sub-sample of several grams was analyzed for each sample. In the gravimetric matrix reduction procedure, organic constituents were removed by ashing, acid-soluble constituents were removed using hydrochloric acid, and large particles were separated by sedimentation. The chrysotile in the material remaining suspended after sedimentation was quantified by optical microscopy using size-selective point counting of prepared filters. Large fiber bundles of chrysotile were hand-picked from the sediment and weighed. In order to quantify any amphibole asbestos present, the sediment remaining from the gravimetric matrix reduction was further separated by heavy liquid centrifugation. Large amphibole asbestos fibers were hand-picked from the

centrifugate and identified by both polarized light microscopy (PLM) and transmission electron microscopy (TEM), and then their dimensions were measured. On mounted point counting filters, amphibole fibers can be classified only on the basis of morphology, birefringence, and optical sign. Accordingly, on the point counting filters, discrimination between amosite and actinolite/richterite asbestos is not possible. Numerically, these amphibole asbestos fibers were infrequent, and did not contribute to the point counting data. The amount of amphibole asbestos on the point counting filters could be quantified, however, by measuring the dimensions of the fibers. The weight percent of amphibole asbestos was calculated from the dimensional measurements made on both the fibers hand-picked from the sediment and the amphibole asbestos fibers observed during the point counting. The weight percent of chrysotile was calculated from the weight of hand-picked fibers and the results of the point counting.

5.3.3 Results

Table 22 presents the summary results of the analyses of samples of exterior dust and debris.

The material collected from the roof of the automobile contained 0.67% chrysotile by weight, and the material collected from the roof outside the 5th Floor loft at 45 Warren Street contained 1.05% chrysotile by weight. Fibers hand-picked from the centrifugates showed that actinolite asbestos and richterite asbestos were present in both of these samples, amosite was present in the sample collected from the roof outside the 5th Floor loft at 45 Warren Street, but no amosite was detected in the sample collected from the roof of the automobile on Church Street. During point counting of filters to determine the presence of chrysotile in these two samples, amphibole asbestos fibers were observed. Because most of the amphibole asbestos hand-picked from these two samples was actinolite/richterite asbestos, it is reasonable to conclude that the fibers on the corresponding point counting filters are also primarily actinolite/richterite asbestos. Based on this assumption, the concentration of actinolite/richterite asbestos in the sample collected from the roof of the automobile on Church

TABLE 22. SUMMARY OF RESULTS OF GRAVIMETRIC ANALYSES FOR ASBESTOS IN EXTERIOR DUST AND DEBRIS

WORLD TRADE CENTER AREA, NEW YORK CITY

Sample	Weight of Sub-Sample Analyzed grams	Weight Percent Amphibole Asbestos			Total Weight Percent Amphibole Asbestos	Total Weight Percent Chrysotile
		Hand-Picked from Centrifugate Following Heavy Liquid Separation		Amphibole Asbestos Detected on Point Counting Slides		
		Amosite	Actinolite/Richterite			
CHURCH STREET, SOUTH OF DUANE STREET Roof of Automobile 17 September, 2001 Gray Fibrous Material	7.7657	None Detected	0.0057	0.0127	0.018	0.67
45 WARREN STREET Roof, Outside 5th Floor Loft Gaps in Stone Floor 18 September, 2001 Gray Fibrous Material	2.2423	0.0004	0.001	0.0196	0.021	1.05
250 SOUTH END AVENUE Apartment 11D Exterior Window Ledge 18 September, 2001 Gray Fibrous Material	7.1188	0.0021	None Detected	0.0139	0.016	2.25
250 SOUTH END AVENUE Ground Level Courtyard Top of Wall 18 September, 2001 Gray Fibrous Material	6.5851	0.0059	None Detected	0.0126	0.019	2.05

Street was approximately 0.018% by weight, and the concentration in the sample collected from the roof outside the 5th Floor loft at 45 Warren Street was approximately 0.021% by weight .

At 250 South End Avenue, the material collected from the exterior window ledge of Apartment 11D contained 2.25% chrysotile by weight, and the material collected from the top of a wall in the ground-level courtyard contained 2.05% chrysotile by weight. In both samples, these results include large fiber bundles equivalent to approximately 0.2% chrysotile by weight, which were hand-picked from the sediment. No actinolite/richterite asbestos was detected in either of these samples. Both of these samples, however, contained low concentrations of amosite. After heavy liquid separation, it was possible to hand-pick fibers of amosite from the centrifugate. During point counting of filters to determine the presence of chrysotile in these two samples, amphibole asbestos fibers were observed. Because all of the amphibole asbestos hand-picked from these samples was amosite, it is reasonable to conclude that the fibers on the corresponding point counting filters are also primarily amosite. Based on this assumption, the concentration of amosite in the sample collected from the exterior window ledge of Apartment 11D was approximately 0.016% by weight, and the concentration of amosite in the sample collected from the top of the wall in the ground level courtyard was approximately 0.019% by weight.

During the analyses, it was observed that the samples collected north of the World Trade Center site, from the automobile on Church Street and the roof outside the 5th Floor loft at 45 Warren Street, contained substantial amounts of vermiculite. The samples collected from 250 South End Avenue contained substantially less vermiculite, but a higher concentration of chrysotile.

Analyses of these four exterior dust and debris samples show that the dust cloud generated by the collapse of the buildings was not homogeneous, and that the dispersed material is different in the two directions from the site. This result would not be surprising if different products had been used in different buildings. Nevertheless, the two samples collected in each of the two different directions relative to the World Trade Center site are very consistent with each other with respect to both the nature of the constituents and the concentrations of chrysotile and amphibole asbestos. The measurements indicate that actinolite/richterite asbestos is probably associated with vermiculite because samples collected to the north of the World Trade Center site

show both, whereas samples collected to the southwest contain much less vermiculite and actinolite/richterite asbestos was not detected. A small amount of amosite was detected in one of the samples taken north of the World Trade Center site, and a higher level of amosite was present in the samples collected at 250 South End Avenue.

6.0 CONCLUSIONS AND RECOMMENDATIONS

The sampling conducted on 18 September 2001 revealed that the concentrations of PCBs, PCDD/PCDFs (expressed as 2,3,7,8-TCDD Equivalents), and inorganic metals (excluding calcium) were generally low or below comparative background levels. However, the concentrations of asbestos found in dust samples and in the air inside the apartments were significantly elevated. Because these air samples were collected under passive conditions, any disturbance of this material could increase the airborne concentrations and potentially increase exposure to asbestos.

The following recommendations can ensure proper cleanup of the asbestos-contaminated dust and reduce exposures of cleanup personnel and occupants returning to the building. Unless proven otherwise through testing, all dust should be assumed to be asbestos-containing.

1) The dust cleanup should be conducted by an environmental contractor with expertise in asbestos contamination cleanup or remediation of hazardous materials. Contractors selected for this work should be licensed by the proper authorities in the City of New York and/or the State of New York for asbestos or hazardous material cleanup activities. Individuals working for these companies should be properly trained by completing asbestos training courses certified by the New York State Department of Health and licensed for asbestos activities by the New York State Department of Labor. In lieu of this requirement, at a minimum, individuals should have Awareness Training in accordance with the OSHA Asbestos Standard, 29 CFR 1926.1101. The training should cover the potential exposures (such as asbestos and caustic irritant dust) that may be encountered during the activities, appropriate personal protective equipment, and work practices.

2) Individuals performing the dust cleanup should be equipped with proper personal protective equipment to reduce exposure to asbestos-containing and alkaline dust. This equipment should include the use of half-face air-purifying respirators that are equipped with high-efficiency particulate air (HEPA) filters. *Note*: The level of respiratory protection can be modified according to the conditions of worker exposure and the airborne level of asbestos. Respiratory protection should be provided in accordance with OSHA Standard 29 CFR 1910.134. Additionally, individuals should use protective clothing such as disposable coveralls or similar whole-body clothing including hoods, boots, and gloves.

3) To reduce dust recirculation, all surfaces (including those inside of cabinets, etc.) should be cleaned using vacuum cleaners equipped with HEPA filters. The surfaces should then be wet-wiped with amended water containing a non-sudsing surfactant. No surface should be dry swept or dusted because this will re-entrain the dust. Upholstery and carpets

should be HEPA-vacuumed and cleaned using either steam or a hot-water extraction method (Kominsky et. al, 1990). All clothing, linens, and other similar items should be laundered.

4) The heating, ventilation, and air-conditioning (HVAC) system should be inspected. If the system was in operation during or after the September 11th incident, it may contain asbestos-contaminated dust. An environmental consultant should be consulted to determine the most efficient procedures to clean the system including the air-handling unit and ventilation ducts (supply and return).

5) A suitable re-occupancy clearance criterion needs to be established. This criterion can be based on a thorough visual inspection and/or air testing.

6) To prevent or minimize the outdoor dust from entering the apartment: (1) keep windows closed and repair all broken glass; (2) set the air-conditioner to re-circulate air (closed vents), change the filter initially and frequently thereafter; and (3) remove shoes before entering the apartment.